

# DevOps

Martin Kellogg

# Reading quiz: DevOps

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Q2: As an example of automation gone awry, the “Emergency Response” article discussed:

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# Announcements

- Reminder: preliminary demos this week. Double-check the time of your team's demo with me.
  - Sorry to those of you who I've had to reschedule
- Team survey #2 will open this afternoon. You should fill it out after you've finished both of your preliminary demos but before the Thanksgiving holiday
- No class on November 26 (one week from today)
  - It's a Friday schedule

# DevOps

Today's agenda:

- **Operations, Toil, and the DevOps philosophy**
- Achieving reliability
  - the service reliability hierarchy + SLAs/targets
  - monitoring and reliability testing
  - incident/emergency response
  - preventing problems before they occur
  - post-mortems + learning from failure

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- deploying new versions of the software

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  - other advantages: easy to staff for, off-the-shelf tooling, etc.

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Traditional approach to operations can work in either of these models!

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    - separation of ops and dev responsibilities are not **directly** related
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    - developers and sysadmins use different terminology, etc., leading to **communication breakdowns**
- These problems **do not** mean that the traditional approach to operations is bad in all circumstances!
- But, they are serious concerns for modern systems with high release cadences, especially those that are:
    - microservices
    - delivered via the web
    - use “continuous delivery”

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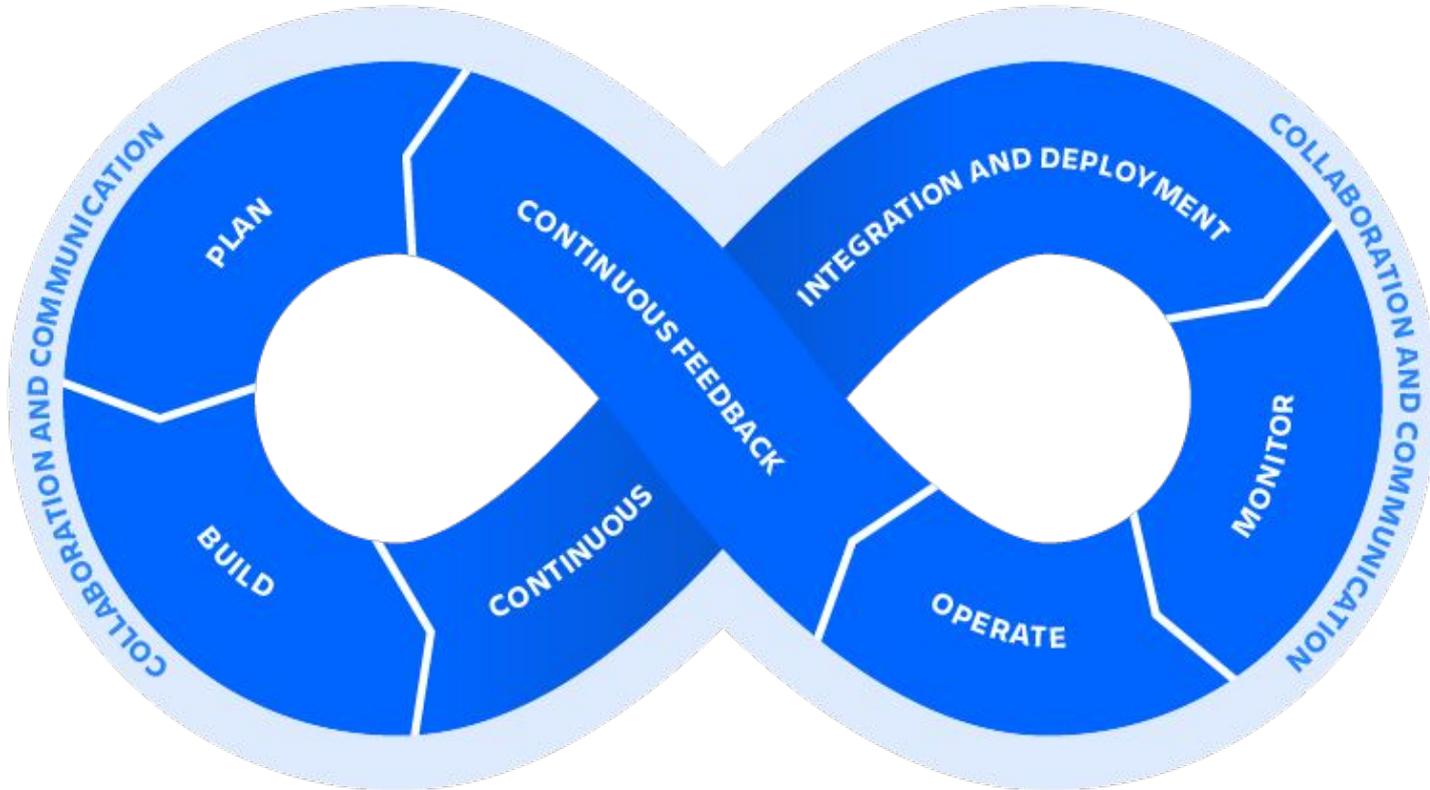
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- operational burden is **shared** by the developers who are building the system
  - better alignment of incentives between developers and operators, since same people perform both roles
- encourage operators to automate **toil**
- may still have some dedicated ops roles (e.g., SREs at Google)

# Operations: the DevOps approach



# Operations: toil

“ *If a human operator needs to touch your system during normal operations, you have a bug. The definition of normal changes as your systems grow.* ”

Carla Geisser, Google SRE

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A key advantage of DevOps is that it encourages **removing** toil

- if operators are separate from devs, devs have no incentive to avoid toil

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- **repetitive:** if you're performing a task for the first time ever, or even the second time, this work is not toil
- **automatable:** if human judgment is essential for the task, there's a good chance it's not toil

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- **no enduring value:** if your service remains in the same state after you have finished a task, the task was probably toil
- **$O(n)$  with service growth:** if the work involved in a task scales up linearly with *service size*, *traffic volume*, or *user count*, that task is probably toil

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- **tactical:** toil
- **no enduring value:** you have finished the task after
- **$O(n)$  with scale:** scales up
- **linearly with scale:** task is
- **probably toil**

A task doesn't need to have **all** of these attributes to be toil. But, the more closely work matches one or more of these descriptors, the **more likely** it is to be toil.

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  - useful, productive work can be unpleasant
    - e.g., cleaning up the entire alerting configuration for your service and removing clutter may not be fun, but it's not toil

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- **overhead** is also different than toil
  - tasks like team meetings, setting and grading goals, and HR paperwork (that are not tied to operations) are overhead

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- career stagnation (it doesn't get you promoted)
- lowers morale (it's boring)
- creates confusion (easy to forget to do a manual task!)
- slows progress (could be doing useful work instead)
- sets precedent (avoid letting toil become normal!)
- promotes attrition (“I want to work on something interesting!”)

# Operations: toil

What's **so bad** about toil?

- career stagnation (it doesn't get you promoted)
- lowers morale (it's boring)
- creates code debt
- slows progress
- sets precedence
- promotes bad habits

Despite all this, a **little bit** of toil is often okay. After all, engineers only have so many productive hours in every day, and sometimes a **mental break** is nice :)

...interesting!")

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  - SRE team manages ops for all of these systems

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- SRE motto: “Hope is not a strategy”

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    - makes technical debt riskier to take on (why?)

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- Operations, Toil, and the DevOps philosophy
- **Achieving reliability**
  - the service reliability hierarchy + SLAs/targets
  - monitoring and reliability testing
  - incident/emergency response
  - preventing problems before they occur
  - post-mortems + learning from failure

# Achieving reliability

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- these two properties are related: an unavailable service **cannot** be correct
  - so, availability is the first thing we need to worry about when trying to make a service reliable

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    - **durability** (how much of your data can you still retrieve after a fixed time has passed)

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Sometimes SLAs are written into contracts with your customers!

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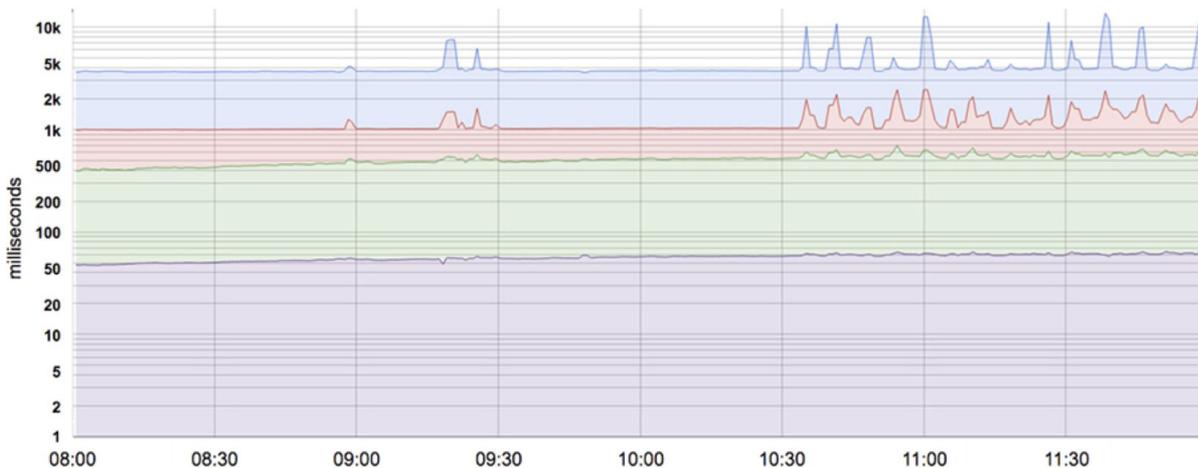
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- E.g., consider two systems:
- system A serves 200 requests in every even-numbered second, and 0 requests in every odd-numbered second
  - system B serves 100 requests every second

# Aside: subtleties in metrics

- It is better to view metrics as **distributions** (as in statistics) rather than as averages
  - this avoids hiding details like the example on the last slide

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purple is  
50th %  
latency

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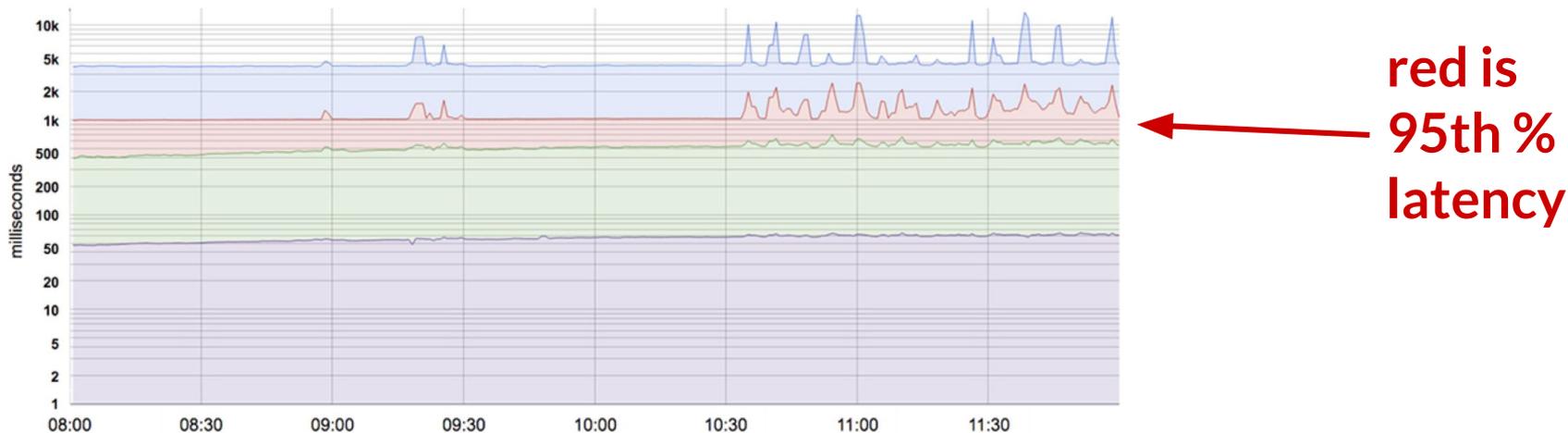
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green is  
85th %  
latency

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latency

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Finally, watch out for **Goodhart's Law**:  
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- regularly re-examine the set of metrics that you're using to make sure they actually correlate with qualitative “good” system health

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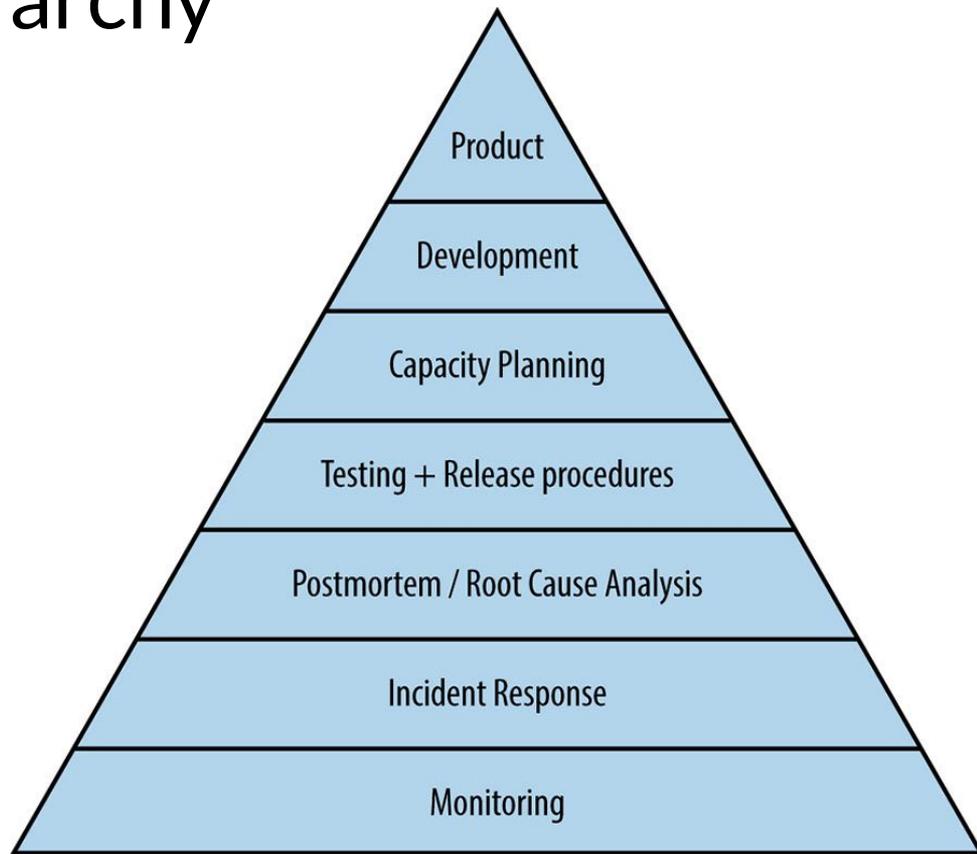
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- How do we think about how to do this?
  - **insight:** there is a **hierarchy** of system components that need to be working well in order to meet an SLA

# Service Reliability Hierarchy

- analogy to Maslow's "Hierarchy of Needs" for humans



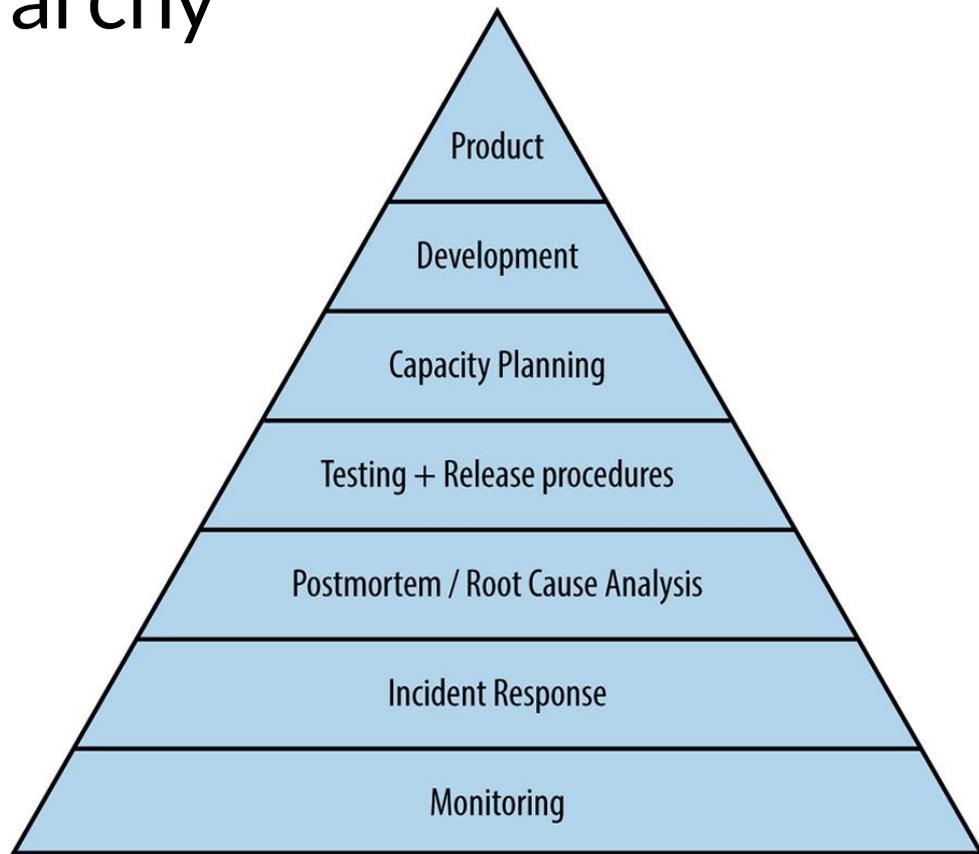
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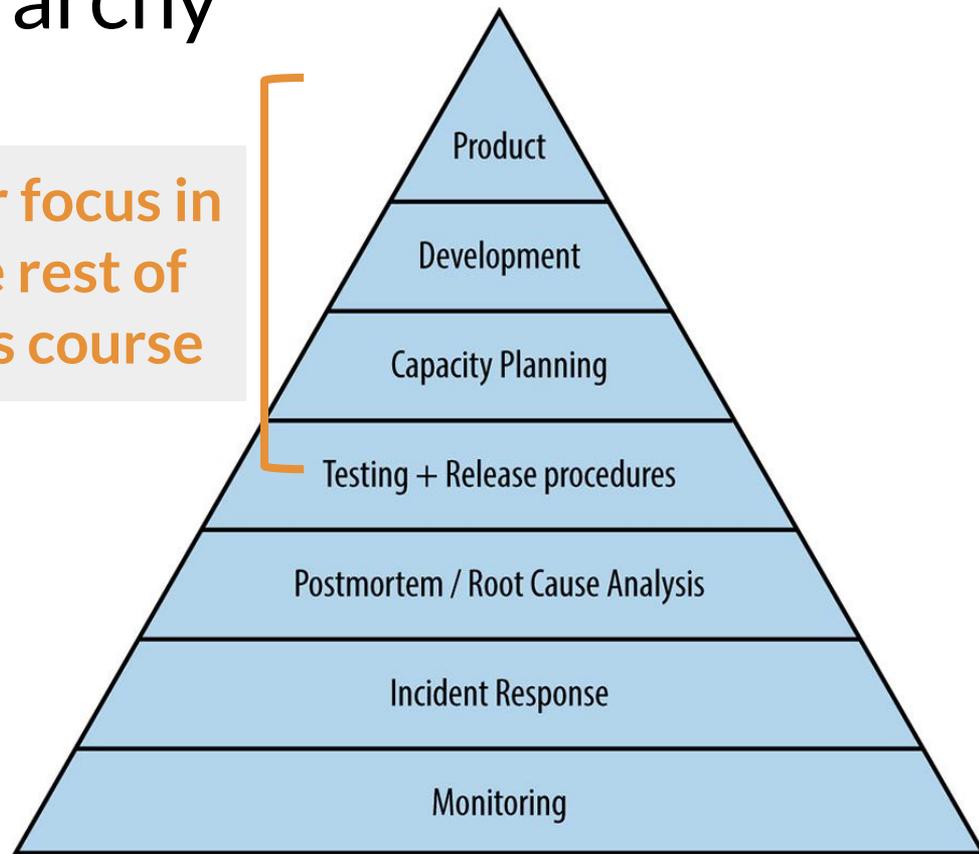
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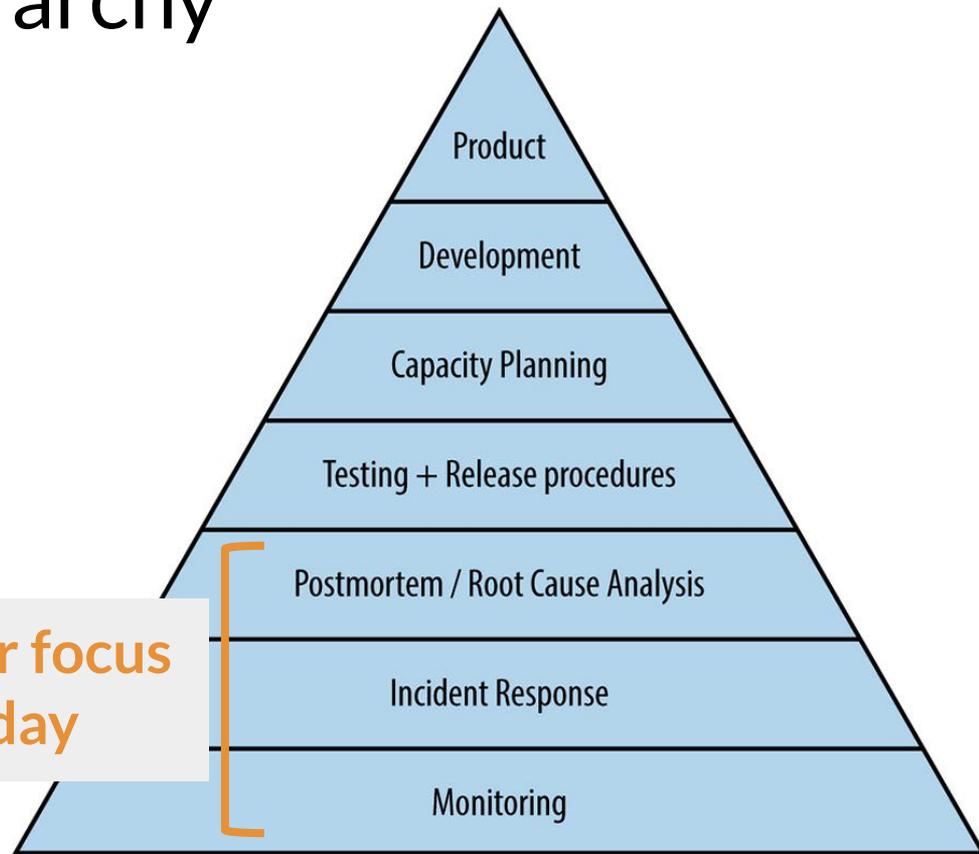
our focus in  
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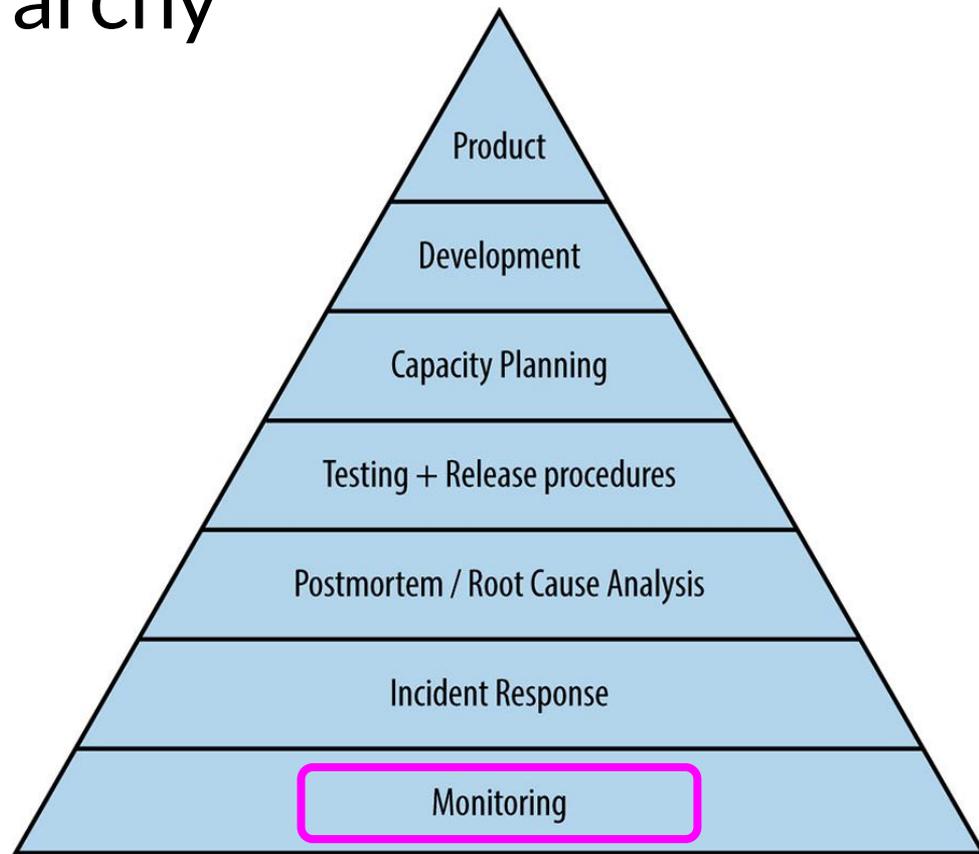
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# DevOps

Today's agenda:

- Operations, Toil, and the DevOps philosophy
- Ops challenge example: deployment
- Achieving reliability
  - the service reliability hierarchy + SLAs/targets
  - **monitoring**
  - incident/emergency response
  - post-mortems + learning from failure

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Monitoring is why **logging** is so important in practice: if your monitoring depends on your logging framework, it is a very important component of your service!

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- **page** = alert send directly to a human (via a pager)

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# DevOps (2/2)

Martin Kellogg

# Reading quiz: DevOps (2)

Q1: Which of these is a role-playing exercise to train new SREs on incident management?

- A. Failure Dice
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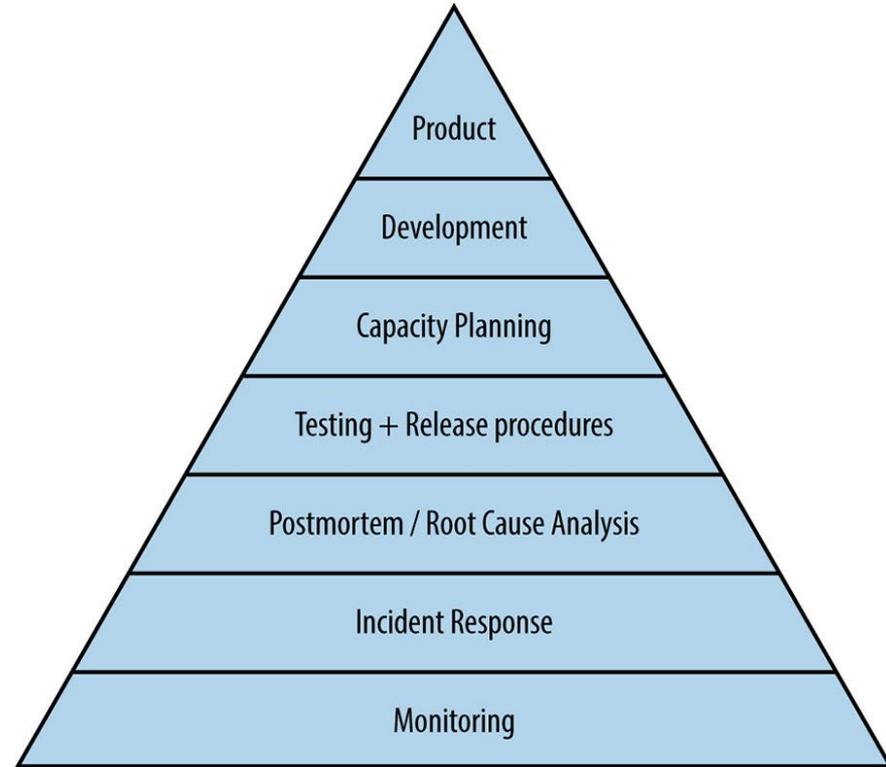
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# Announcements

- Team survey #2 is open. Please fill it out before you leave for Thanksgiving break.
- No class on Wednesday
  - University has declared it to be a Friday
- Enjoy your break!

# Review: Service Reliability Hierarchy

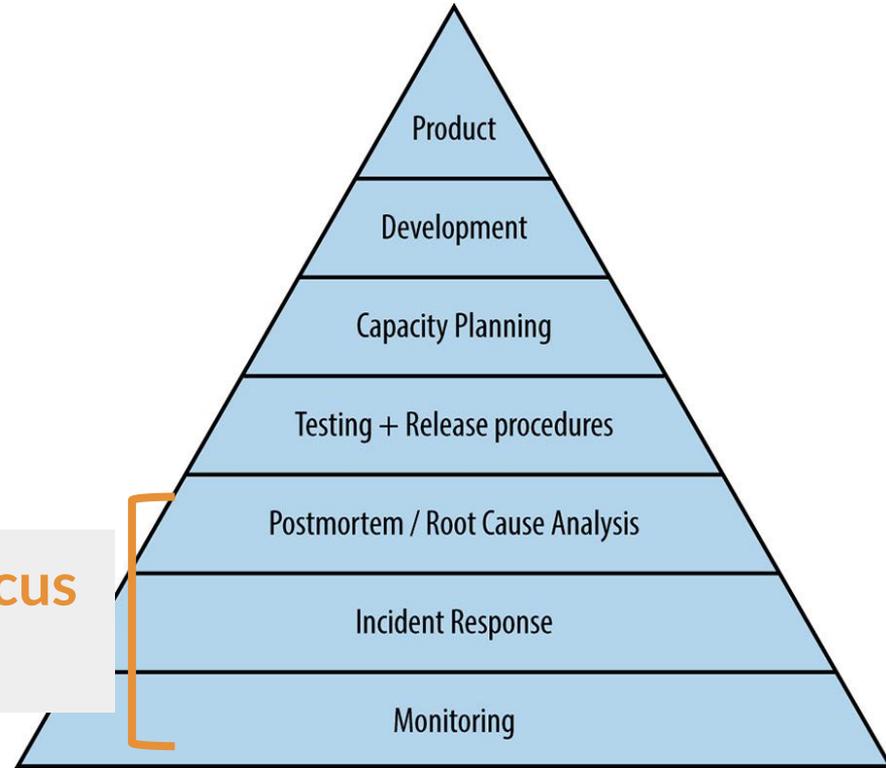
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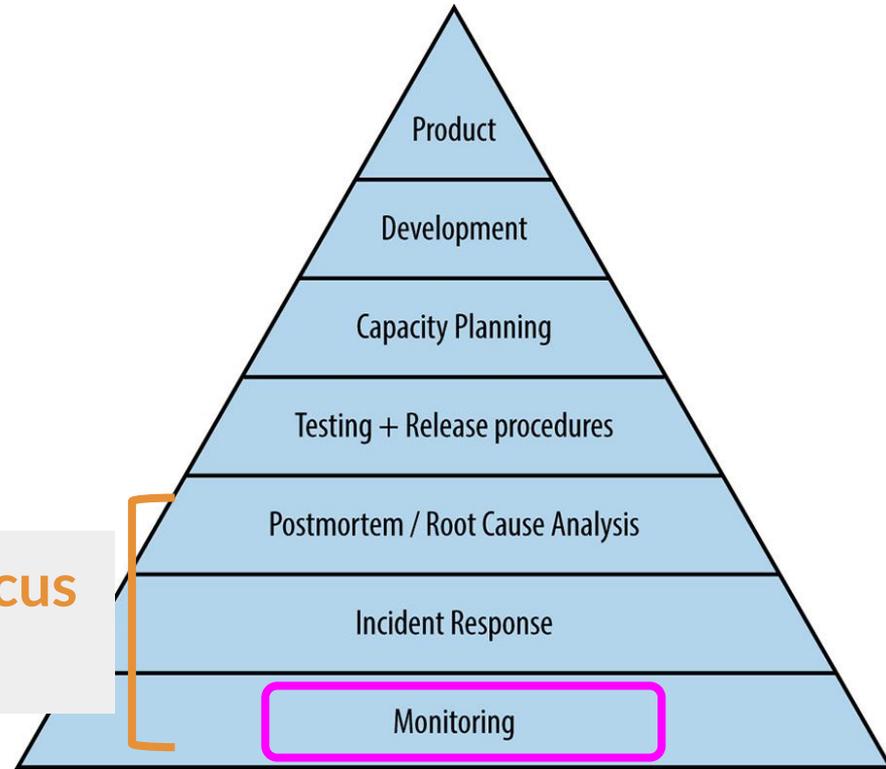
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  - Or it might be a **page** to the on-call engineer, if the problem needs to be investigated right away

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- Example from Monday: “cleaning up a service’s alerting config” = fixing **what corresponds** to pages vs email alerts vs tickets

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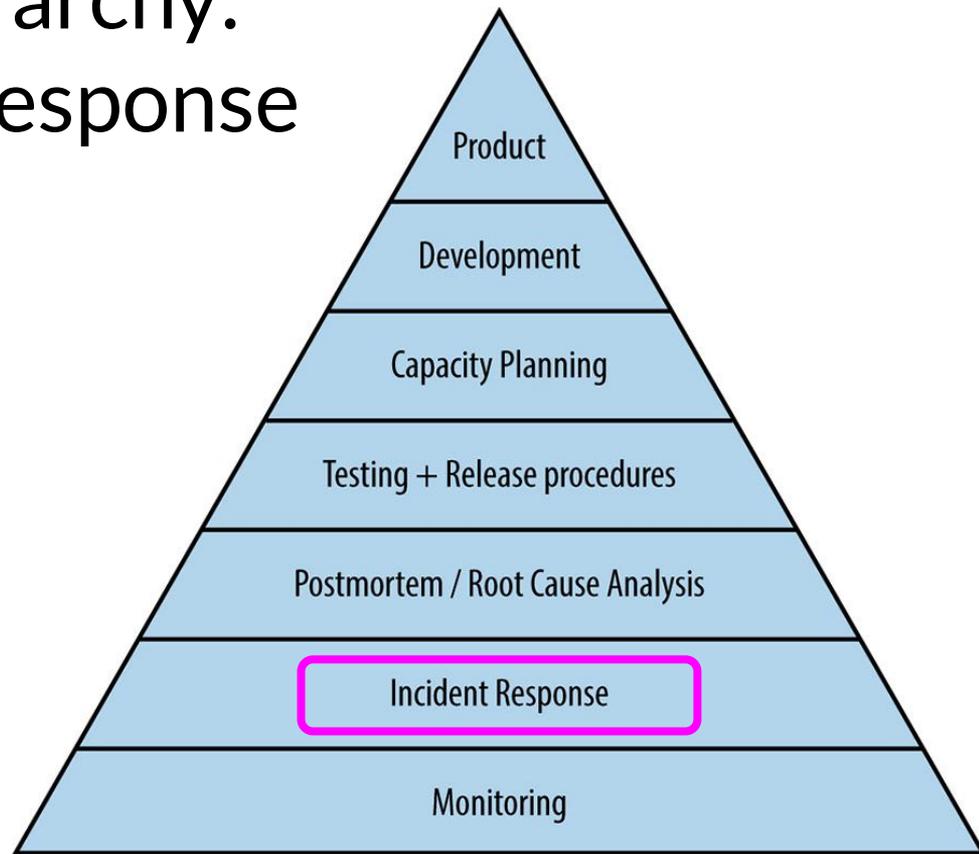
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  - but can (**and should**) page other team members in an emergency

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  - the service reliability hierarchy + SLAs/targets
  - monitoring and reliability testing
  - **incident/emergency response**
  - preventing problems before they occur
  - post-mortems + learning from failure

# Service Reliability Hierarchy: Incident/Emergency Response



# Emergency Response

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  - as the on-call, **you are in charge** in an emergency by default
- What constitutes an emergency?
  - depends on your service, but typically these qualify:
    - big % of user requests aren't getting responses
    - big % of user requests have really high latency
    - lots of your servers are unavailable/down (even if users aren't yet impacted)

# Emergency Response: causes of emergencies

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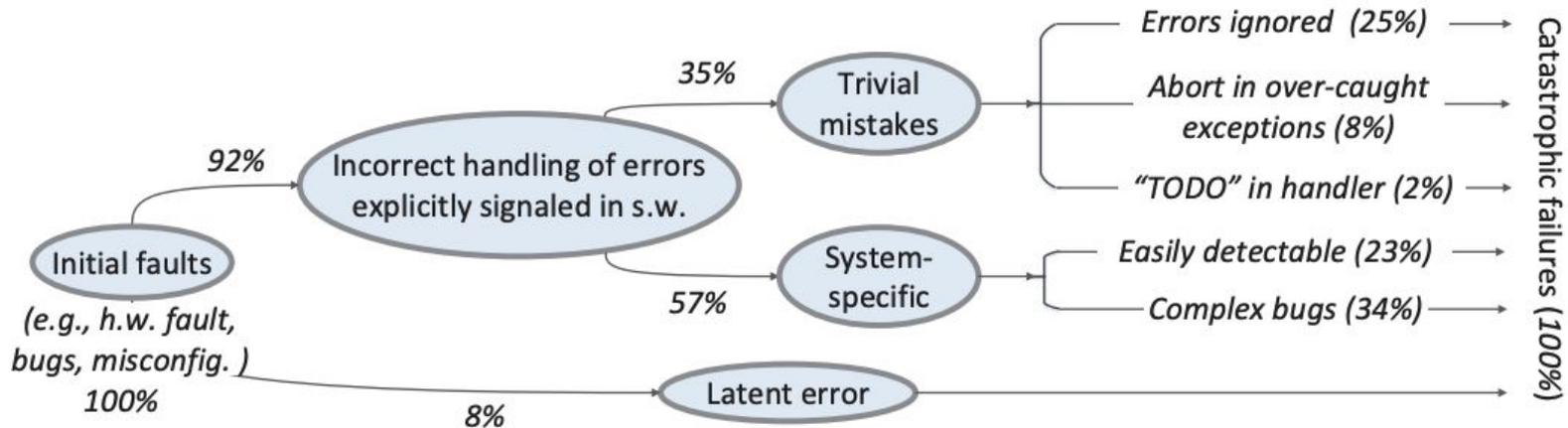
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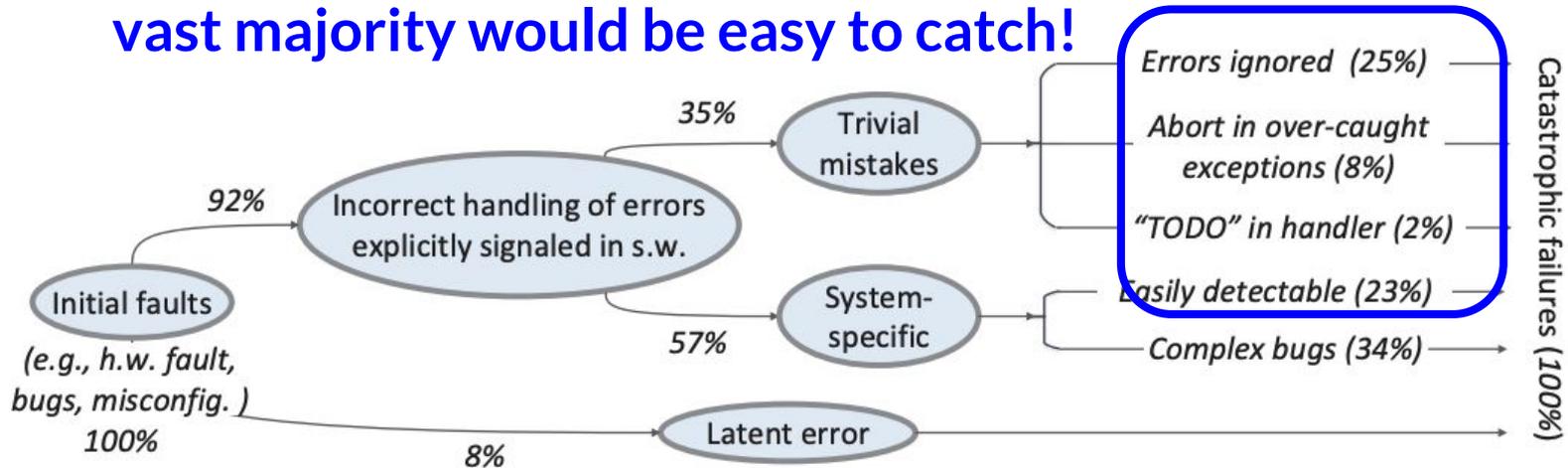
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**vast majority would be easy to catch!**



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# Emergency Response: causes of emergencies

- **configuration changes:**
  - especially for services, how the servers that run the system are configured is often as important as the code itself
  - changes to the infrastructure (e.g., adding or removing servers) are just as risky as changes to the code
    - but testing them is harder!

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- **almost 100%!**
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Implication: in large systems, you  
**must plan for hardware failures,**  
because they **will occur**

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    - computers are good at this!
    - analogy: just like hardware components sometimes fail, any step carried out by humans should be assumed to have a non-zero failure rate

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  - playbooks also have a psychological function: **prevent panic**

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  - **preserve evidence**: save logs, etc., for post-mortem analysis

# Emergency Response: best practices

- Know your priorities:
  - **damage control**: take proactive steps to prevent the incident from becoming worse (e.g., remove unnecessary traffic)
  - **restore service**: get the service back to a healthy state, even if you aren't sure about the cause (e.g., by rolling back recent changes)
  - **preserve evidence**: save logs, etc., for post-mortem analysis
- **Practice** makes perfect
  - don't wait for an actual emergency to find out if your playbook works: simulate one instead!

# Emergency Response: rolling back

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    - make sure to commit things that might cause incidents if they change to version control, e.g., your **config files**

# Emergency Response: rolling back

- One of the most important things is to be able to **rolling back** to the last known good state.
  - key idea: most emergency incidents are caused by changes that are not reversible
  - so, to fix the incident, you need to be able to roll back to the last known good state

Easy rollbacks are one motivation for “**infrastructure-as-code**”: if your infrastructure configuration is in version control, it’s easy to go back to the last working one!

- The need to roll back has important implications:
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  - your version control system is your friend here!
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# DevOps

Today's agenda:

- Operations, Toil, and the DevOps philosophy
- Achieving reliability
  - the service reliability hierarchy + SLAs/targets
  - monitoring and reliability testing
  - incident/emergency response
  - **preventing problems before they occur**
  - post-mortems + learning from failure

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# Preventing Problems

- while it's important to have a plan for responding to emergencies, it's better if they **never happen at all**
  - we can use many of the techniques that we discussed in this class to help prevent emergencies!
- however, there are some **DevOps-specific** testing and deployment strategies that can help:
  - integrating testing and monitoring
  - stress testing services
  - canaries and “baking the binary”

# Integrating Testing and Monitoring

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  - for example, should there be a **relationship** between a pair of metrics that we’re collecting? (= **metamorphic testing**)
    - if so, we can define an alert that goes off if that relationship is ever violated

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- Stress tests answer questions like:
  - “How full can a database get before writes start to fail?”
  - “How many queries a second can be sent to an application server before it becomes overloaded, causing requests to fail?”
- **Chaos Monkey** is one example of a stress testing technique
  - Others include intentionally **scaling up** another service
    - i.e., simulate a spike in demand with artificial traffic

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- *“Imagine a monkey entering a “data center”, these “farms” of servers that host all the critical functions of our online activities. The monkey **randomly** rips cables, destroys devices and returns everything that passes by the hand. The challenge for IT managers is to **design the information system** they are responsible for **so that it can work despite these monkeys**, which no one ever knows when they arrive and what they will destroy.”*

– Antonio Martinez, Chaos Monkey

# Stress Testing: Chaos Monkey

- *“We have created Chaos Monkey, a program that randomly chooses a server and disables it during its usual hours of activity. Some will find that crazy, but we could not depend on the random occurrence of an event to test our behavior in the face of the very consequences of this event.”*
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    - many parts of the system have failed, not just one!
  - one of the goals of Chaos Monkey is to detect such cascading failures before they actually happen in production

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  - in a staged deployment, a small **percentage** of the active fleet is upgraded.
    - this part of the fleet is monitored for failures, and if none occur then **more and more** of the fleet is updated

This incubation period while the fleet is partially upgraded is sometimes called "**baking the binary**".

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  - $U$  = order of the fault (see next slide)
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  - $K$  = the period over which the traffic grows by a factor of  $e$

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Note that **C**, **R**, and **K** should all be **measurable** by your monitoring system. but that is **exponential**

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  - **U=2**: each request randomly damages data that a future request may see.
  - **U=3**: the randomly damaged data is also a valid identifier to a previous request.

Observe that *order* here is like big-O notation:

- U=1 means that only the request itself is impacted
- U=2 means that a linear-ish number of other requests will be impacted
- U=3 means exponentially more requests will be impacted
- etc.

know

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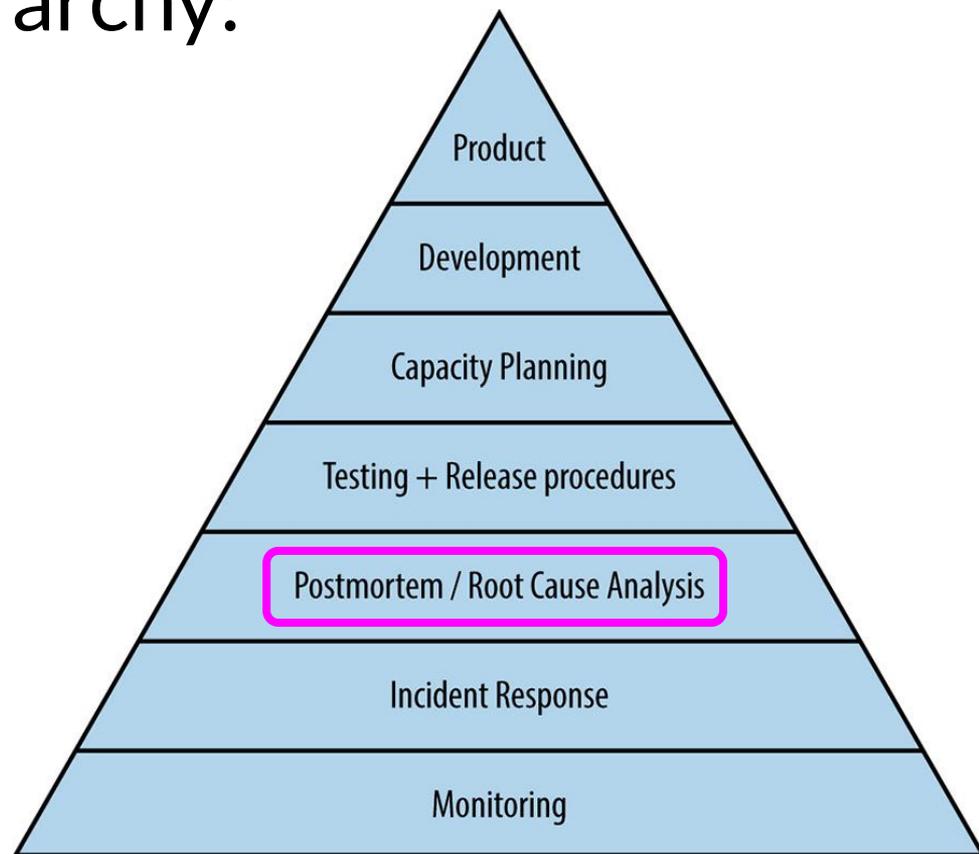
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    - this might involve writing automation to trace all requests that hit the bug, restoring from a backup, etc.
- As we do all of this, it's important to **keep records**
  - they'll be useful later for **writing the post-mortem** (next topic!)

# DevOps

Today's agenda:

- Operations, Toil, and the DevOps philosophy
- Achieving reliability
  - the service reliability hierarchy + SLAs/targets
  - monitoring and reliability testing
  - incident/emergency response
  - preventing problems before they occur
  - **post-mortems + learning from failure**

# Service Reliability Hierarchy: Post-mortems



# Post-mortems

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- good postmortems are **blameless** and **actionable**:
  - “**blameless**” = find the faults in the process, not the people
  - “**actionable**” = give specific guidance for how to avoid the problem in the future (these become tickets)

# Post-mortems: blameless

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  - After all, **someone** should be responsible, right?

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  - After all, **someone** should be responsible, right?
- Some reasons:
  - Gives people **confidence to escalate** issues without fear
  - Avoids creating a culture in which incidents and issues are **swept under the rug** (which is worse long-term!)
  - **Learning experience**: engineers who have experienced an incident won't make the same mistakes again
  - You can't "fix" people, but you can fix **systems and processes**

# Post-mortems: blameless

- Why not assign blame?
  - After all, **some** people are to blame
- Some reasons:
  - Gives people **confidence** to report errors
  - Avoids creating **blame culture** where mistakes are **swept under the rug**
  - **Learning experience**: engineers who have experienced an incident won't make the same mistakes again
  - You can't "fix" people, but you can fix **systems and processes**

Historically, software engineering adopted a lot of "blameless culture" from **aviation and medicine**, where mistakes can be fatal! We might not have the same stakes, but **all complex systems are similar** in a lot of ways.

# Post-mortems: peer review

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- Peer review **raises the bar**: senior engineers on other teams will expect you to **explain and justify** the changes you are proposing in response to an incident
  - leads to more actionable takeaways and better understanding of what went wrong
  - also enables engineers on different teams to learn from each others' mistakes

# Post-mortems: example

## Shakespeare Sonnet++ Postmortem (incident #465)

**Date:** 2015-10-21

**Authors:** jennifer, martym, agoogler

**Status:** Complete, action items in progress

**Summary:** Shakespeare Search down for 66 minutes during period of very high interest in Shakespeare due to discovery of a new sonnet.

**Impact:**<sup>163</sup> Estimated 1.21B queries lost, no revenue impact.

**Root Causes:**<sup>164</sup> Cascading failure due to combination of exceptionally high load and a resource leak when searches failed due to terms not being in the Shakespeare corpus. The newly discovered sonnet used a word that had never before appeared in one of Shakespeare's works, which happened to be the term users searched for. Under normal circumstances, the rate of task failures due to resource leaks is low enough to be unnoticed.

**Trigger:** Latent bug triggered by sudden increase in traffic.

[ source: <https://sre.google/sre-book/example-postmortem/> ]

# Post-mortems: example

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**Date:** 2015-10-21

**Authors:** jennifer, martym, agoogler

**Status:** Completed

**Summary:** Shakespeare Sonnet++  
a new sonnet.

**Impact:**<sup>163</sup> Estimated 100% query time, no revenue impact.

**Resolution:** Directed traffic to sacrificial cluster and added 10x capacity to mitigate cascading failure. Updated index deployed, resolving interaction with latent bug. Maintaining extra capacity until surge in public interest in new sonnet passes. Resource leak identified and fix deployed.

**Detection:** Borgmon detected high level of HTTP 500s and paged on-call.

**Root Causes:**<sup>164</sup> Cascading failure due to combination of exceptionally high load and a resource leak when searches failed due to terms not being in the Shakespeare corpus. The newly discovered sonnet used a word that had never before appeared in one of Shakespeare's works, which happened to be the term users searched for. Under normal circumstances, the rate of task failures due to resource leaks is low enough to be unnoticed.

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# Post-mortems: example

Action Item	Type	Owner	Bug
Update playbook with instructions for responding to cascading failure	mitigate	jennifer	n/a <b>DONE</b>
Use flux capacitor to balance load between clusters	prevent	martym	Bug 5554823 <b>TODO</b>
Schedule cascading failure test during next DiRT	process	docbrown	n/a <b>TODO</b>
Investigate running index MR/fusion continuously	prevent	jennifer	Bug 5554824 <b>TODO</b>

[ source: <https://sre.google/sre-book/example-postmortem/> ]

Plug file descriptor leak in search ranking prevent

agoogle

Bug 5554825 **DONE**

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**and 5 more...**

Plug file descriptor leak in search ranking prevent

agoogle

[ source: <https://sre.google/sre-book/example-postmortem/> ]

Bug 5554825 **DONE**

# Post-mortems: example

## Lessons Learned

### What went well

- Monitoring quickly alerted us to high rate (reaching ~100%) of HTTP 500s
- Rapidly distributed updated Shakespeare corpus to all clusters

### What went wrong

- We're out of practice in responding to cascading failure
- We exceeded our availability error budget (by several orders of magnitude) due to the exceptional surge of traffic that essentially all resulted in failures

### Where we got lucky<sup>166</sup>

- Mailing list of Shakespeare aficionados had a copy of new sonnet available
- Server logs had stack traces pointing to file descriptor exhaustion as cause for crash
- Query-of-death was resolved by pushing new index containing popular search term

[ source: <https://sre.google/sre-book/example-postmortem/> ]

# Post-mortems: example

## Timeline<sup>167</sup>

2015-10-21 (all times UTC)

- 14:51 News reports that a new Shakespearean sonnet has been discovered in a DeLorean's glove compartment
- 14:53 Traffic to Shakespeare search increases by 88x after post to [/r/shakespeare](#) points to Shakespeare search engine as place to find new sonnet (except we don't have the sonnet yet)
- 14:54 **OUTAGE BEGINS** — Search backends start melting down under load
- 14:55 docbrown receives pager storm, `ManyHttp500s` from all clusters
- 14:57 All traffic to Shakespeare search is failing: see <https://monitor>
- 14:58 docbrown starts investigating, finds backend crash rate very high
- 15:01 **INCIDENT BEGINS** docbrown declares incident #465 due to cascading failure, coordination on `#shakespeare`, names jennifer incident commander
- 15:02 someone coincidentally sends email to `shakespeare-discuss@` re sonnet discovery, which happens to be at top of martym's inbox

# Post-mortems: example

## Timeline<sup>167</sup>

2015-10-21 (all times UTC)

- 14:51 News reports that a new Shakespearean sonnet has been discovered in a DeLorean's glove compartment
- 14:53 Traffic to Shakespeare search increases by 88x after post to [/r/shakespeare](#) points to Shakespeare search engine as place to find new sonnet (except we don't have the sonnet yet)
- 14:54 **OUTAGE BEGINS** — Search backends start melting down under load
- 14:55 docbrown receives pager storm, `ManyHttp500s` from all clusters
- 14:57 All traffic to Shakespeare search is failing: see <https://monitor>
- 14:58 docbrown starts investigating, finds backend crash rate very high
- 15:01 **INCIDENT BEGINS** docbrown declares incident #465 due to cascading failure, coordination on

**this goes on for several pages!**

- **shows importance of keeping records**

opens to be at

[ source: <https://sre.google/sre-book/example-postmortem/> ]

# DevOps: takeaways

- Many modern engineering organizations prefer to combine, rather than separate, development and operations
  - this works best when most systems are services
- Major benefit of DevOps approach is elimination of toil
  - developers are best at building automation
- Planning for incidents/emergencies is critical
  - Monitoring allows on-call to quickly identify problems
  - Have a plan (ideally, in a playbook) for incidents
  - Use post-mortems to learn from prior emergencies
    - not to blame people for causing them!

